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Effect of El-Nino on rainfall and Production of major crops and strategies to enhance the productivity of Eastern Plain Zone of U.P.

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Abstract
District wise monthly rainfall data of Eastern Plain Zone of Uttar Pradesh recorded for the period of 1981 to 2017 were used under the present study. The total rainfall for the summer (March to May), South-West monsoon (June to September), Rabi (October - December) and winter (January - February) seasons were computed year wise for various districts of Eastern Plain Zone of U.P. The analysis was performed to assess the association between El-Nino episodes and rainfall and crop production & crop productivity of Eastern Plain Zone of UP. The average South-West monsoon rainfall, summer rainfall, winter rainfall, and total annual rainfall received during the years with El-Nino were found to be less as compared to normal years, In general, the South-West monsoon rainfall and the annual rainfall was found less during the El-Nino years. The average area, production, and productivity of crops were found to decrease during El-Nino years thereby indicating the risk associated with short duration crops grown under rainfed conditions during the Kharif season. The yield of long duration rabi crops like wheat, chickpea, pea, mustard, etc. grown either on residual soil moisture or irrigated were comparatively less affected during the El-Nino years. There is a need to enhance the agricultural production and productivity of crops during the El-Nino years. As the South-West monsoon rainfall and annual rainfall are likely to less than normal in the region. Short duration crops and varieties as main crops/intercropping system can be adopted in the zone. The productivity of Rabi crops can be improved by the judicious use of fertilizers and the adoption of insect pests & disease control during the early stages of its growth. Plantation crops like fruit and timber plants are likely to yield decline due to a decrease of pre-monsoon rainfall and therefore moisture conservation practices need to be adopted.

Keywords: Climatic variability, rainfall, El-Nino, production, productivity, major crops

Introduction
Rainfall is the direct source for both rainfed and irrigated agriculture. In general, it drives the agricultural productivity of India. The quantum and the distribution of rainfall determine agricultural productivity. In Eastern Plain Zone of Uttar Pradesh, it determines not only the crop selections during the Kharif season but also the crop sequences in double-cropping systems in rabi seasons. Thus the monsoon rainfall and its distribution are very crucial for crop success in Eastern Plain Zone of Uttar Pradesh. Some regions of India receive normal, some parts receive below normal, while some others receive above-normal rainfall. This type of spatial distribution of rainfall is important from the angle of agricultural planning. El-Nino is one of the most important factors that govern monsoonal rainfall over India. Assessment of the role of El-Nino on regional rainfall and agriculture has been attempted for the states of Andhra Pradesh (Rao. *et al*., 2011) [7], Gujarat (Patel *et al*., 2014) [5] and Karnataka (Venkatesh *et al* 2015) [8]. Among several factors that govern agricultural production, the weather appears to be the most critical factor as the farmers have no control over it, and its inter and intraseasonal variability' sare difficult to predict with greater reliability and confidence. So, the farmers generally believe that the weather in the coming year will be different from what they were aware of in the past. Prasanna (2014) [6] studied that the focuses on understanding the variations of precipitation during summer monsoon season and its impact on Kharif and rabi foodgrain yield over India. Total foodgrain yield over India during Kharif (summer) season is directly affected by variations in the summer monsoon precipitation (June-September). Hansen and Jones (2000) and Park (2001) [4] observed that recent advances in atmospheric and oceanic research, much of it focusing on El-Nino Southern oscillation and its teleconnections made it possible to forecast climate with useful skill with lead times of several months. Pandey *et al.* (2018) [3] analyzed the ENSO event has a profound impact on summer monsoonal rainfall across

India and most of the major droughts have occurred during El-Nino events. El-Nino resulting in deficit rainfall tends to lower the summer crop production such as rice, sugarcane, cotton, and oilseed, and therefore the outcome might be seen in form of high inflation rates and lower GDP due to high contribution of agriculture sector in the Indian economy. There is a need to enhance the agricultural production and productivity of crops during the El-Nino year. Hence keeping the above facts in view the present investigation was undertaken.

Materials and Methods

Study area

District wise monthly rainfall data of Eastern Plain Zone of Uttar Pradesh recorded during the years 1981 to 2017 were used in the present study. The total rainfall for the summer (March to May), South-West monsoon (June to September), rabi (October-December) and winter (January-February) seasons were computed year wise for various districts of Eastern Plain Zone of U.P.

District wise Crop data

The average area, production, and productivity of major food grains in different districts of Eastern Plain Zone of U.P. for the years 1981 to 2017 were obtained from Directorate of Economics and Statistics, Government of U.P. Average production of major crops was worked out for the nine selected districts for the period. The average area, production & productivity of the crops in the El-Nino years was worked out and comparison was made with overall average normal value.

According to Jan Null (2011), the Oceanic Nino Index (ONI) has become the defect standard that NOAA uses for identifying El-Nino (Warm) and La-Nina (Cool) events in the tropical pacific for the Nino 3.4 region (i.e., 5^0 N to 5^0 6, 120^0 -170^0 W). Events are defined as five consecutive months at or above the +0.5 ^{0}C anomaly for warm (El-Nino) events. The threshold is further broken down into weak with a 0.5 to 0.9 sea surface temperature anomaly, Moderate (1.0 to 1.4), and Strong (1.5) events

Results and Discussion

Seasonal rainfall

The percentage change in seasonal rainfall during the El-Nino years compared to normal rainfall was computed for the seasons in different districts. The average rainfall during the South-West (S-W) monsoon season during the El-Nino years was less than the normal rainfall in all the districts of Eastern Plain Zone of U.P. The departure was maximum in Jaunpur district by 9.2 percent followed by Barabanki district (9.0%). The lowest departure (1%) was recorded in the Mau district of Eastern Plain Zone of the U.P.

The average summer season rainfall during El-Nino years from March to May was less than the normal rainfall in Eastern Plain Zone of U.P. The maximum departure (10.1percent) was recorded in Ghazipur district followed by 8.4% in Barabanki district. The minimum departure (1%) over normal rainfall was recorded in Ballia district.

The average rainfall during winter season during El-Nino years from January to February was less than the normal rainfall in all the districts of Eastern Plain Zone of U.P. as evident in Table 1. The maximum departure (14.9%) was recorded in Ghazipur district followed by Jaunpur district. The average rainfall during the post-monsoon (October to December) during El-Nino years was almost less than the normal rainfall in Eastern Plain Zone of U.P. during the El-Nino years as compared to normal rainfall.

Annual rainfall

Table 1: Percent change in average seasonal rainfall (mm) during El-Nino years as compared to normal years rainfall (mm) in Eastern Plain Zone of U.P. (1981-2017).

Name of Districts	Winter (JAN-FEB)			Summer (MAR-MAY)			SW Monsoon (JUN-SEPT)			Post Monsoon (OCT-DEC)		
	El Nino (Y)	N (Y)	PC*	El Nino (Y)	N (Y)	PC*	El Nino (Y)	N (Y)	PC*	El Nino (Y)	N (Y)	PC*
Varanasi	82	87.7	-6.5	67	72.7	-7.8	876	926.7	-5.5	58	67.4	-13.9
Jaunpur	48	53.9	-10.9	78	84.4	-7.6	805	886.2	-9.2	70	72.2	-3.0
Ghazipur	40	47	-14.9	67	74.5	-10.1	910	929.8	-2.1	44	66.5	-33.8
Ballia	44	46.3	-5.0	70	70.7	-1.0	913	892.2	2.3	58	67.4	-13.9
Azamgarh	47	51.8	-9.3	76	78.4	-3.1	873	899.7	-3.0	75	73.6	1.9
Mau	44	48	-8.3	74	80	-7.5	890	900	-1.0	60	65	-7.7
Faizabad	72	79.8	-9.8	109	103.5	5.3	860	891.3	-3.5	90	86.8	3.7
Sultanpur	63	66.7	-5.5	93	100.6	-7.6	825	886.9	-7.0	75	72.5	3.4
Barabanki	58	64	-9.4	81	88.4	-8.4	800	878.7	-9.0	68	74.8	-9.1

* PC indicates the percent change

Table 2: Percent change in district-wise average annual rainfall (mm) during El-Nino years as compared to normal years rainfall in Eastern Plain Zone of U.P. (1981-2017).

Name of Districts	Rainfall (mm)		
	El-Nino years	Normal years	Percentage change
Varanasi	1083	1079	0.4
Jaunpur	937	987	-5.1
Ghazipur	1005	1034	-2.8
Ballia	927	983	-5.7
Azamgarh	1003	1031	-2.7
Mau	1044	1070	-2.4
Faizabad	985	1001	-1.6
Sultanpur	990	1005	-1.5
Barabanki	1044	1056	-1.1

Table 3: Percent change in District wise average area sown (ha), production (tons), and yield (kg/ha) of Rice during El-Nino year compared to normal years of Eastern Uttar Pradesh.

Name of Districts	Area			Production			Yield		
	El-Nino	Normal	PC*	El-Nino	Normal	PC	El-Nino	Normal	PC
Varanasi	50495	51719	-2.4	120135	131832	-8.9	2379	2549	-6.7
Jaunpur	152654	157278	-2.9	348461	362683	-3.9	2282	2306	-1.0
Ghazipur	152548	154815	-1.5	377651	384251	-1.7	2475	2482	-0.3
Ballia	113014	115681	-2.3	280014	289550	-3.3	2477	2503	-1.0
Azamgarh	214325	216041	-0.8	481573	512233	-6.0	2246	2371	-5.3
Mau	90014	91322	-1.4	204876	217894	-6.0	2276	2386	-4.6
Faizabad	99145	101927	-2.7	254876	263889	-3.4	2570	2589	-0.7
Sultanpur	94156	95969	-1.9	295487	306621	-3.6	3138	3195	-1.8
Barabanki	175649	181604	-3.3	497894	520659	-4.4	2834	2867	-1.2

Table 4: Percent change in District wise average area sown (ha), production (tons), and yield (kg/ha) of Maize during El-Nino year compared to normal years of Eastern Uttar Pradesh.

Name of Districts	Area			Production			Yield		
	El-Nino	Normal	PC*	El-Nino	Normal	PC	El-Nino	Normal	PC
Varanasi	2634	2899	-9.1	4587	5143	-10.8	1741	1774	-1.9
Jaunpur	42346	43086	-1.7	64728	66654	-2.9	1528	1547	-1.2
Ghazipur	615	628	-2.1	540	622	-13.2	878	991	-11.4
Ballia	27897	28303	-1.4	52864	53776	-1.7	1894	1900	-0.3
Azamgarh	5364	5555	-3.4	8646	8999	-3.9	1611	1620	-0.6
Mau	291	298	-2.3	545	552	-1.3	1872	1854	1.0
Faizabad	1346	1463	-8.0	2246	2468	-9.0	1668	1687	-1.1
Sultanpur	4237	4395	-3.6	7118	7414	-4.0	1679	1687	-0.5
Barabanki	3446	3547	-2.8	5731	5984	-4.2	1663	1687	-1.4

Table 5: Per cent change in District wise average area sown (ha), production (tons), and yield (kg/ha) of Wheat during El-Nino year compared to normal years of Eastern Uttar Pradesh.

Name of Districts	Area			Production			Yield		
	El-Nino	Normal	PC*	El-Nino	Normal	PC	El-Nino	Normal	PC
Varanasi	68953	69363	-0.6	231185	234528	-1.4	3352	3381	-0.9
Jaunpur	204271	207669	-1.6	711468	735148	-3.2	3482	3540	-1.6
Ghazipur	164510	166213	-1.0	488249	494151	-1.2	2967	2973	-0.2
Ballia	134970	136892	-1.4	483479	495067	-2.3	3582	3616	-0.9
Azamgarh	231396	235094	-1.6	784628	808724	-3.0	3390	3440	-1.5
Mau	93975	95373	-1.5	340141	352975	-3.6	3619	3701	-2.2
Faizabad	105742	109263	-3.2	398975	412905	-3.4	3773	3779	-0.2
Sultanpur	112464	114555	-1.8	450486	461653	-2.4	4005	4030	-0.6
Barabanki	165120	168346	-1.9	655046	677088	-3.3	3967	4022	-1.4

The percentage change in district-wise average annual rainfall during the El-Nino years as compared to normal rainfall of different selected districts of Eastern Plain Zone of U.P. has been given in Table 2. The average annual rainfall during El-Nino years is less than normal years. Maximum departure (5.7%) was recorded in Ballia district followed by Jaunpur district (5.1%) as evident in Table 4.2. The lowest departure of 0.4% was found in Varanasi district followed by Barabanki district (1.1%) of Eastern Plain Zone of U.P.

The average annual rainfall and South-West monsoon season rainfall were less than normal rainfall during the years with El-Nino. Hence, El-Nino unambiguously serves as a signal of deficit rainfall for the Eastern Plain Zone of U.P. during the southwest monsoon season and if it does not happen, leads to deficit annual rainfall.

Area, Production, and Productivity of Major Crops

Rice

The district-wise average of area, production, and yield of Rice during the years with El-Nino compared to the remaining years has been given in Table 3. The average area, production, and productivity of rice crop of different districts were less during El-Nino years as compared to normal value. The maximum decline in the area (3.3%) was recorded in the Barabanki district followed by 2.9% Jaunpur district. However, the minimum area decline of 0.8% was recorded in the Azamgarh district. The maximum decline in production (8.9%) was recorded in Varanasi district followed by 6% in Azamgarh and Mau district. However minimum production decline by 1.7% was recorded in Ghazipur district. The maximum decline in productivity 6.7% was recorded in Varanasi district followed by a 5.3% decline in Azamgarh district. The minimum decline in productivity by 0.3% was recorded in the Ghazipur district of Eastern Plain Zone of the U.P.

Maize

The district-wise average of area, production, and yield of Maize during the years with El-Nino compared to the remaining years has been given in table 4. The average area, production, and productivity of Maize crop of different districts were less during El-Nino years as compared to normal value. The maximum decline in the area (9.1%) was recorded in Varanasi district followed by 8.0% Faizabad district. The maximum departure in production of maize (13.2%) over normal was found in Ghazipur district followed

by a 10.8% decline over normal was in Varanasi district while minimum (1.3%) in Mau district. Data pertaining to yield, the maximum decline due to El-Nino over normal (11.4%) was found in Ghazipur district followed by Varanasi district (1.9%) while minimum departure in yield of maize (0.3%) was found in Ballia district of Eastern Plain Zone of U.P.

Wheat

District wise average of area, production, and yield of Wheat during the years with El-Nino compared to the remaining years has been given in Table 5. The average area, production, and productivity of wheat crop of different districts were less during El-Nino years as compared to normal value. The maximum decline in the area (3.2%) was recorded in the Faizabad district followed by 1.9% Barabanki district. However, the minimum area decline by 0.6% was recorded in the Varanasi district. The maximum decline in the production of wheat (3.6%) was recorded in the Mau district while the minimum decline was 1.2% in Ghazipur district. However, data pertaining to yield, the maximum decline due to El-Nino over normal (2.2%) was recorded in Mau district followed by 1.6% decline in Jaunpur district while minimum (0.2%) in Ghazipur and Faizabad district of Eastern Plain Zone of U.P.

Conclusion

District wise monthly rainfall data for various districts of Eastern Plain Zone of Uttar Pradesh recorded during the years 1981 to 2017 were used under the present study. The total rainfall for the summer (March to May), South-West monsoon (June to September), Rabi (October-December) and winter (January to February) seasons were computed year wise for various districts of Eastern Plain Zone of U.P. The inter-seasonal and intra-seasonal variability in weather is believed in recent years to outsmart the abilities of climatologist and statisticians in defining the limits within which these variabilities can be observed. The analysis was performed to assess the association between El-Nino episodes and rainfall and crop production & crop productivity in Eastern Plain Zone of U.P. The average South-West monsoon rainfall, summer rainfall, Winter rainfall, and total annual rainfall received during the years with El-Nino were found to be less compared to normal years, In general, it was observed that either the South-West monsoon rainfall and the annual rainfall was found less during the El-Nino years. The average area, production, and productivity of major crops were found to decrease during El-Nino years thereby indicating the risk associated with short duration crops grown under rainfed conditions during the Kharif season. Yield of long duration rabi crops like wheat, chickpea, pea, mustard, etc. grown either on residual soil moisture or irrigated was comparatively less affected during the El-Nino years. There is a need to enhance the agricultural production and productivity of crops during the El-Nino years. As the S-W monsoon rainfall and annual rainfall are likely to less than normal in the region. Short duration crops and varieties as main crops/intercropping system can be adopted in the region. The productivity of Rabi crops can be improved by the judicious use of fertilizers and the adoption of insect pests & disease control during the early stages of its growth. Plantation crops like fruit and timber plants are likely to yield decline due to a decrease of pre-monsoon rainfall and therefore moisture conservation practices need to be adopted. El-Nino is a possible option to understand climate variability and use it for taking strategic decisions for enhancing agriculture production during the seasons with adverse climate to a certain extent.

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